Hydraulic Power Unit for Hydrostatic Bearings

This project is focused on two hydraulic power units (HPU) for hydrostatic (oil) bearings. The first unit powers the hydrostatic bearings of a precision machine tool axis; the second powers those of a precision machine tool spindle. In this project, a precision machine tool is defined as a machine capable of nanometer position control with 50 nm accuracy throughout the work volume of the machine. The two hydraulic units cover a range of thermal heat loads and bearing flow rates to maintain a high degree of stable pressure and temperature control.

Key factors addressed are computer models that aid in the construction of hydrostatic fluid pressure and temperature control systems; a system controller that provides PID and logic functions, with an integrated interface to a machine tool controller; and an operator interface to provide data trending and error notification.

Figure 1 shows a block diagram of the pressure and temperature control system for an oil hydraulic power unit for hydrostatic bearings.

Project Goals

The goals in the second year of this project are to complete the assembly and testing of the two HPU systems. Changes were made this year in the system controller hardware to minimize programming efforts. Modernized temperature signal conditioning electronics are to be completed. Tests of the system are to be conducted to verify the system computer models.

Relevance to LLNL Mission

LLNL has a long history of contributions to the field of precision engineering and precision machine tool design. Some of our machines support fabrication of NIF KDP final optics, weapons compoonents and metrology equipment for a number of programs. This project supports the ability to build new precision machines and to modernize older ones, for to achieve nanometer level of machine performance, it is essential to control the pressure and temperature of the bearing fluid for hydrostatic bearings.

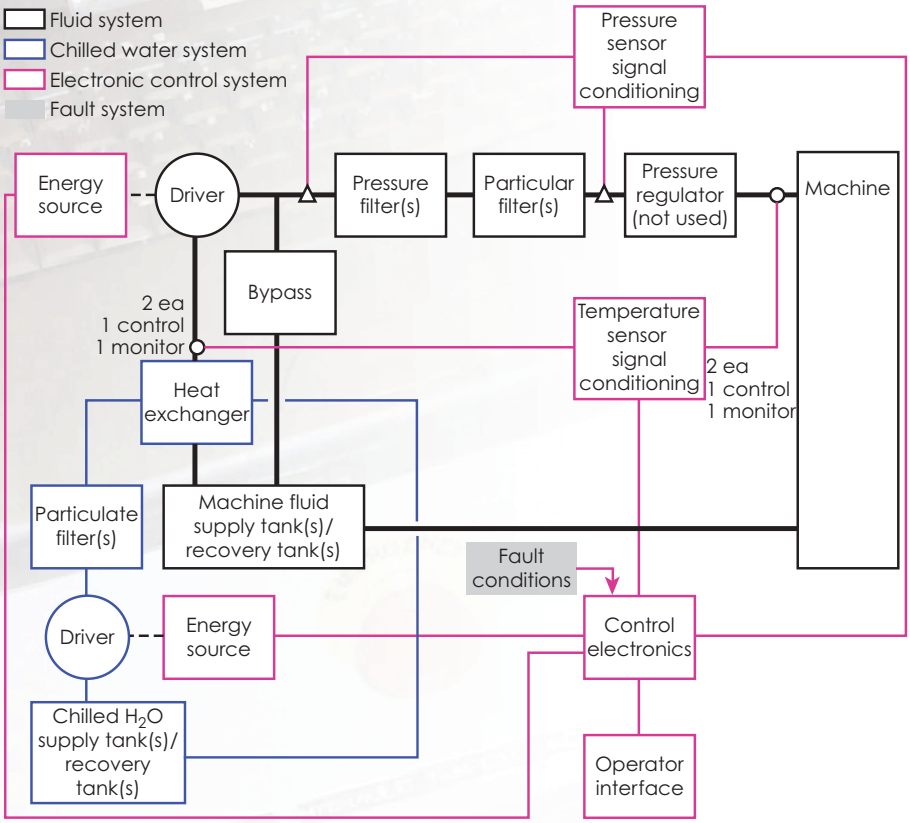

Figure 1. Block diagram of the pressure and temperature control system of the HPU.

For more information contact
David J. Hopkins
(925) 423-6134
hopkins3@llnl.gov

FY2005 Accomplishments and Results

In this second year we completed the mechanical assembly of the two HPUs and two mechanical low-pass filters. We also completed the electronic control system enclosures. The project's electronic control system must provide an operator interface for status and data trending of pressure and temperature. In addition, it must support cascaded or dual-PID control loops. The inner control loop is the faster responding loop and is sensed at the controlling source. The outer loop is slower responding and is sensed at the delivery point of the machine. To create these capabilities and to minimize programming time, new controller hardware was chosen this year that provides the required bandwidth and allows the complete system to be programmed in one language, LabView (Fig. 2).

Last year we worked on modernized AC-bridge signal-conditioning electronics for temperature sensing at millidegree levels (20 mV/m°C). In this second year, we completed the assembly of two four-channel thermistor signal-conditioning boards (Fig. 3).

Testing done this year confirms our ability to maintain a desired set-point in pressure, with a pressure fluctuation of under 0.1% directly out of the pump. This value is primarily at the fundamental of pump gear meshing frequency. It is further attenuated through the mechanical low-pass filter.

The frequency spectrum of the pressure transducer directly out of the pump is shown in Fig. 4.

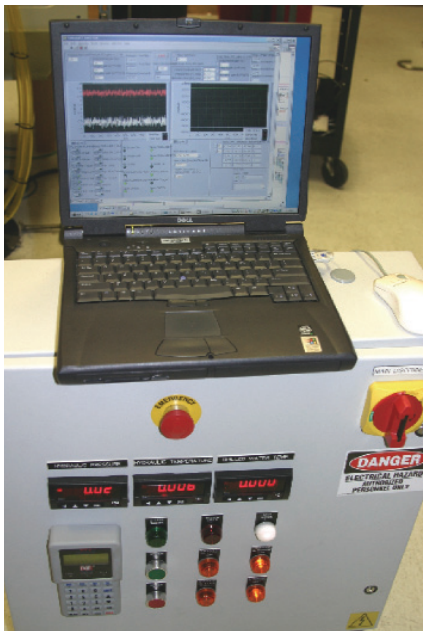

Figure 2. Front panel of HPU and a network-interfaced laptop with LabView set-point and data trending display.

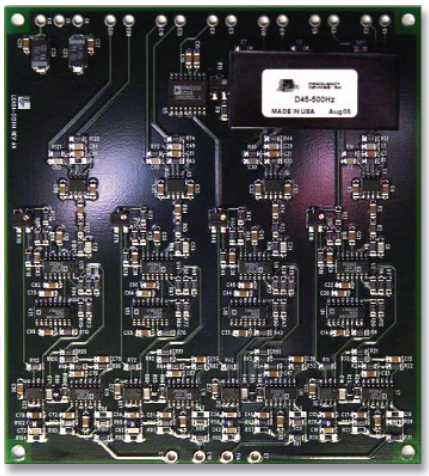

Figure 3. High-sensitivity four-channel thermistor signal-conditioning board for temperature control.

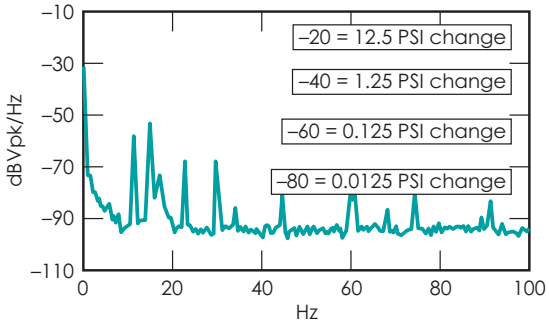

Figure 4. Pressure noise spectrum directly measured at the pump output at 320 psi operating pressure. The first accumulator was charged to 250 psi.

Related References

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2. Viersma, T., Analysis, Synthesis, and Design of Hydraulic Servosystems and Pipelines, Elsevier Publishing Co., New York, 1980.
3. Stansfield, F., Hydrostatic Bearings for Machine Tools, Machinery Publishing Co., Ltd, London, 1970.